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NASA CR-
144488

ONS N76-19522

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08G Unclas
G3/43 00219

SR No. 330 E7.6-10219

HYDROGEOLOGICAL INVESTIGATIONS IN THE PAMPA OF ARGENTINA

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(Federal Geological Survey)

3 Hannover 23
Stilleweg 2, Postfach 23 01 53
Fed. Rep. of Germany

November 1974

Type III Report

Bundesanstalt für Bodenforschung

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und Rohstoffe

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REPORT STANDARD TITLE PAGE

1. SR No. 330	2. Type of Report final	3. Recipient's Catalog No.
4. Title Hydrogeological Investigations in the Pampa of Argentina		5. Report Date May 1975 6. Period Covered
7. Principal Investigator Dr. Dieter Bannert		8. No. of Pages 7
9. Name and Address of Principal Investigators Organization Bundesanstalt für Geowissenschaften und Rohstoffe (Federal Institute for Geosciences and Natural Resources)		10. Principal Investiga. Rept. No 11. GSFC Technical Monitor Ryborn R. Kilby
12. Sponsoring Agency Name and Address Bundesanstalt für Geowissenschaften und Rohstoffe 3 Hannover 51, Stilleweg 2, Postfach 51 01 53 Fed. Rep. of Germany		13. Key Words (Selected by Principal Investigator) Hydrogeology, ground water salinity, pedology

14. Supplementary Notes

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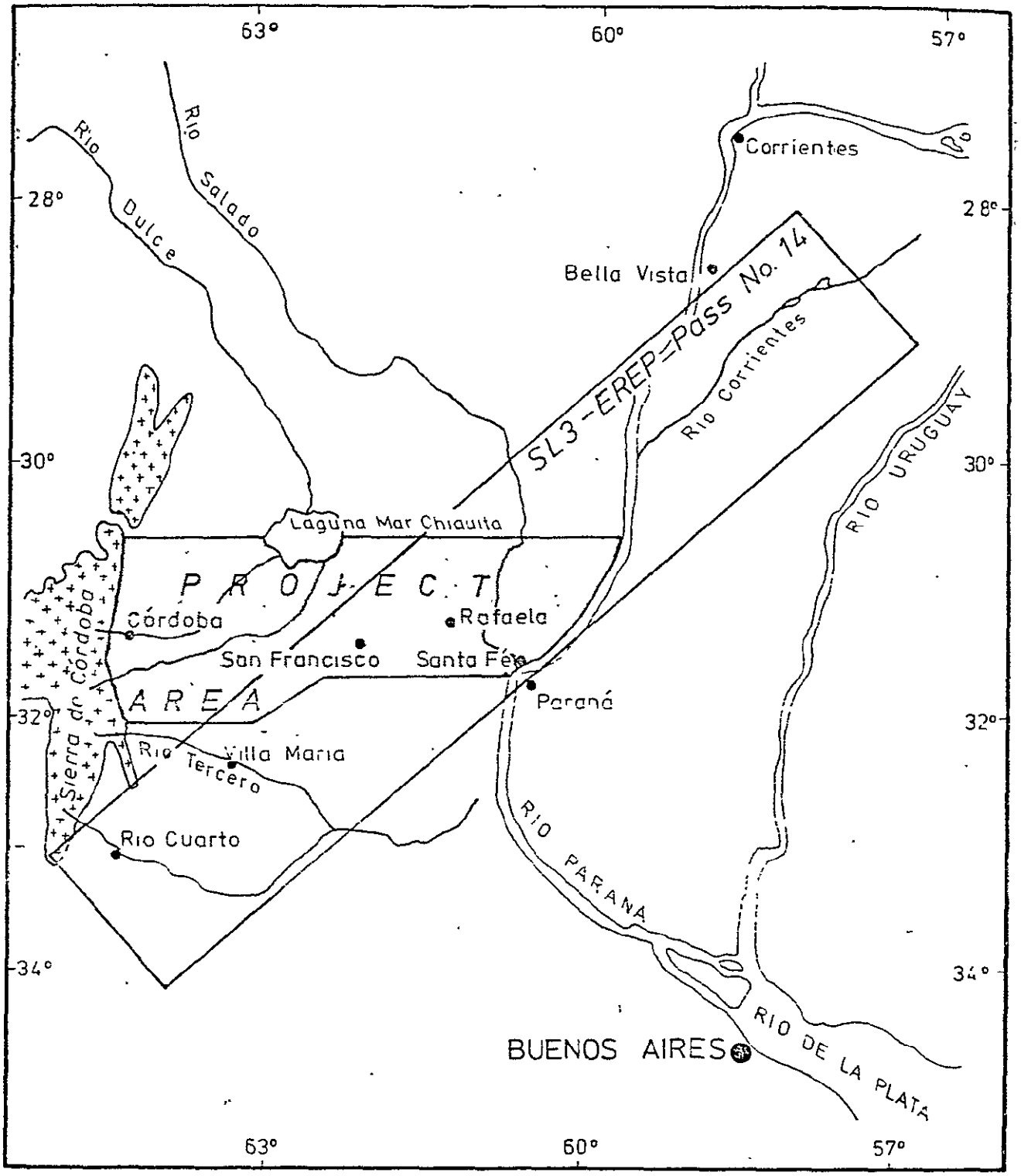
The analysis was mainly carried out by W. Kruck supported in the pedological field by W. Kantor.
Parts of the results have been presented at the following meeting:
Commitee on Space Research (COSPAR) Sao Paulo, 1974

15. Abstract

Investigations of Satellite imagery (Landsat-1 and Skylab), which were based on an extensive ground survey, revealed that differences in the vegetation cover are closely related to depth and salinity of ground water.
The use of satellite imagery in the future will make it possible to improve the accuracy of ground water quality maps, in areas with similar hydrogeological conditions and thereby reduce the field costs considerably.



Outline map of the project area and EREP-pass coverage

Fig. 1

INTRODUCTION

The lack of fresh ground water for consumption by humans and livestock in the Argentinian Pampa led to an intensive hydrogeological investigation in an area of about 50,000 km^2 situated between the Sierra de Córdoba in the West and the Rio Paraná in the East (Fig. 1).

The ground survey was carried out by the Institute of Geoscience and Natural Resources of Germany, in cooperation with Argentinian Organizations, Mineria y Geologia and Subsecretaría de Recursos Hídricos.

In the scope of a NASA project (SR No. 330) the value of Landsat-1 and Skylab data was to be put to the test with regard to the hydrogeological problems.

Initially Landsat-1 imagery covering the whole project area was used for the investigation. The results have been represented in a final NASA report.

Skylab photos available later covered only half the project area but included additional areas in the Northeast and Southwest. From the Skylab photography use was made mainly of IR color photos as these represented contrasts most clearly.

GEOLOGICAL AND HYDROGEOLOGICAL CONDITIONS OF THE PAMPA

In the project area the water level of an upper ground water body, developed in quaternary loess sediments, is situated between 0-20 m below the surface. The ground survey revealed a relationship between morphology, depth to ground water and salinity of ground water. This relationship is reflected by a number of features and units at the earth's surface and can therefore be observed on Landsat-1 and Skylab imagery.

Areas with saline and fresh ground water due to different depths to ground water

The area under investigation is generally characterized by the relatively high salt content of the near - surface ground water. However the salt content of the ground water differs considerably from place to place.

Regions with a ground water table of less than about 5-7 m appear light blue in Skylab IR color photos (Fig. 2 .). High evapotranspiration in the loess sediments results in increased soil and ground water salinity which leads to unfavourable conditions for certain plant species. These areas are favoured predominantly by halophytes.

The best growth conditions prevail in regions where the ground water levels are situated below the area of influence of evapotranspiration (approx. 10 m or deeper).

In Skylab IR color photos these areas are mainly reddish colored, indicating that they are densely covered by vegetation with a high chlorophyll content.

> Generally ground water mineralisation increases with decreasing depth to ground water. It can be assumed that the effect of evaporation acts to a depth of about 3 m. Transpiration by plants increases the potential pumplift by 2 to 7 m.

"Bajos"

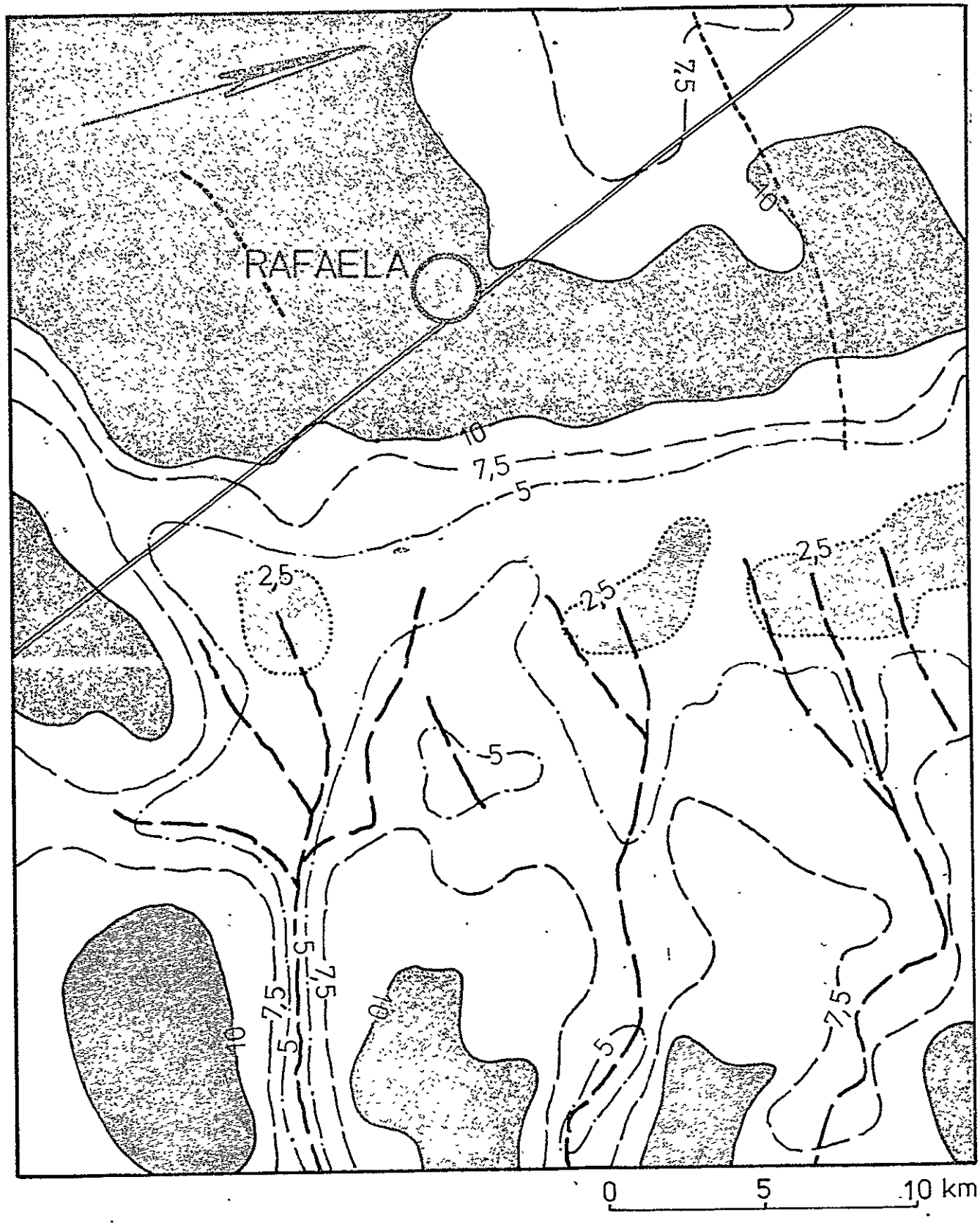
Bajo is the Argentinian term used to describe elongated flat depressions without surface drainage. In satellite imagery they appear as sharply defined strips. They run more or less straight in a ENE-WSW direction, are usually between 100-200 m wide and are spaced at relatively even distances of approx. 2 km, as can be seen in satellite imagery (Fig. 2 b and Fig. 4).

The consistant pattern of the bajos throughout the Pampa region suggests a tectonic origin, probably due to fractures in the deep underlying crystalline bedrock.

After heavy rainfall water collects in the bajos. It is here that more water infiltrates than in the vicinity. As a result fresh water lenses are formed, under the bajos, in the saline ground water body, thereby offering water supply possibilities for rural needs (Fig. 3).

Geophysical research and pumping tests revealed that for the calculation of fresh water reserves (salt content lower than 1 g/l), a medium thickness of 20 m can be assumed. The volume of the fresh water impregnated sediment

Depth to ground water after field survey and Skylab photography



5 Isolines of depth to ground water in meters

Depth to ground water more than 10 m

Depth to ground water less than 2,5m

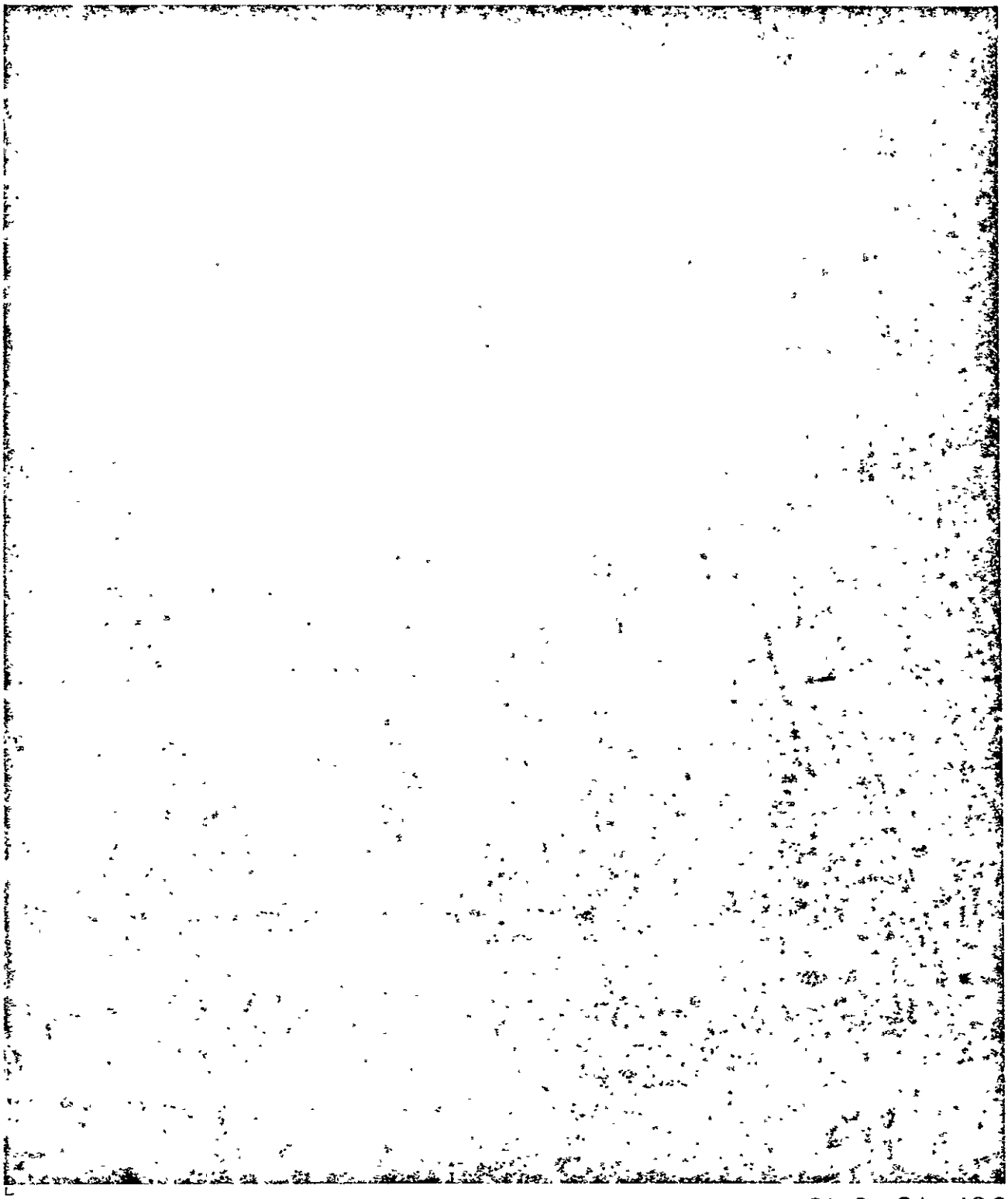
Road

Bajo

Water course

Fig. 2a

The Rafaela region in infrared color



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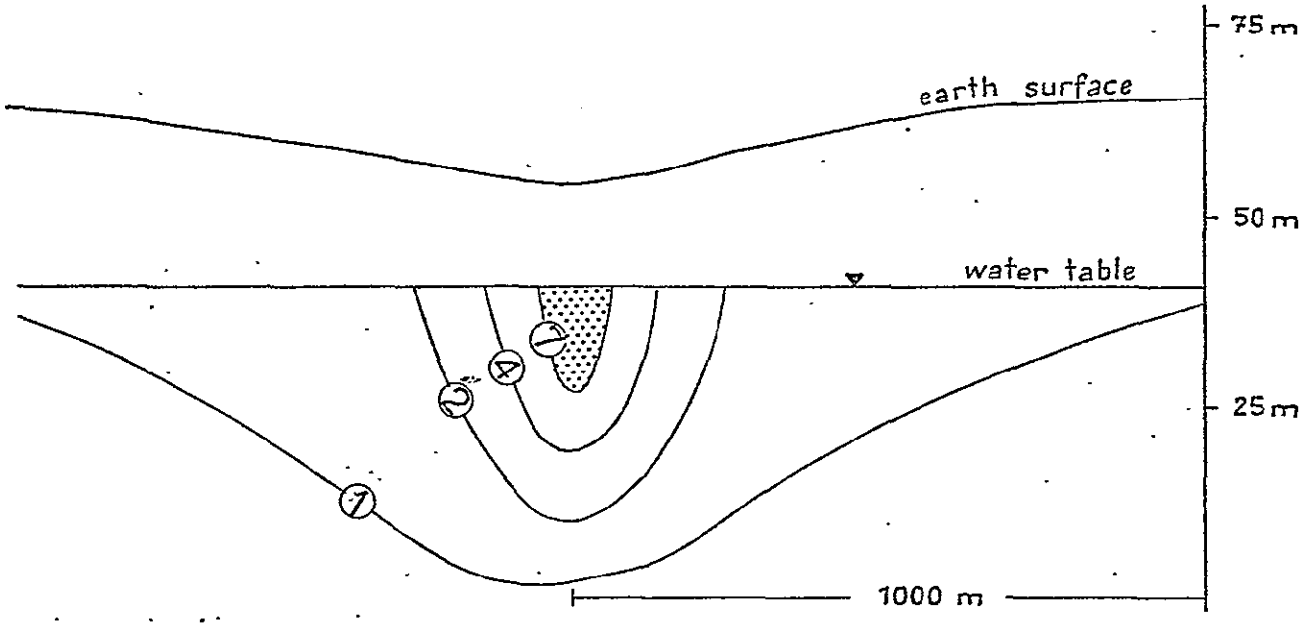
Intensity of vegetation indicating depth to ground water

Fig. 2b

SIMPLIFIED CROSS SECTION OF A "BAJO"

(with the aid of geo-electrical profiles)



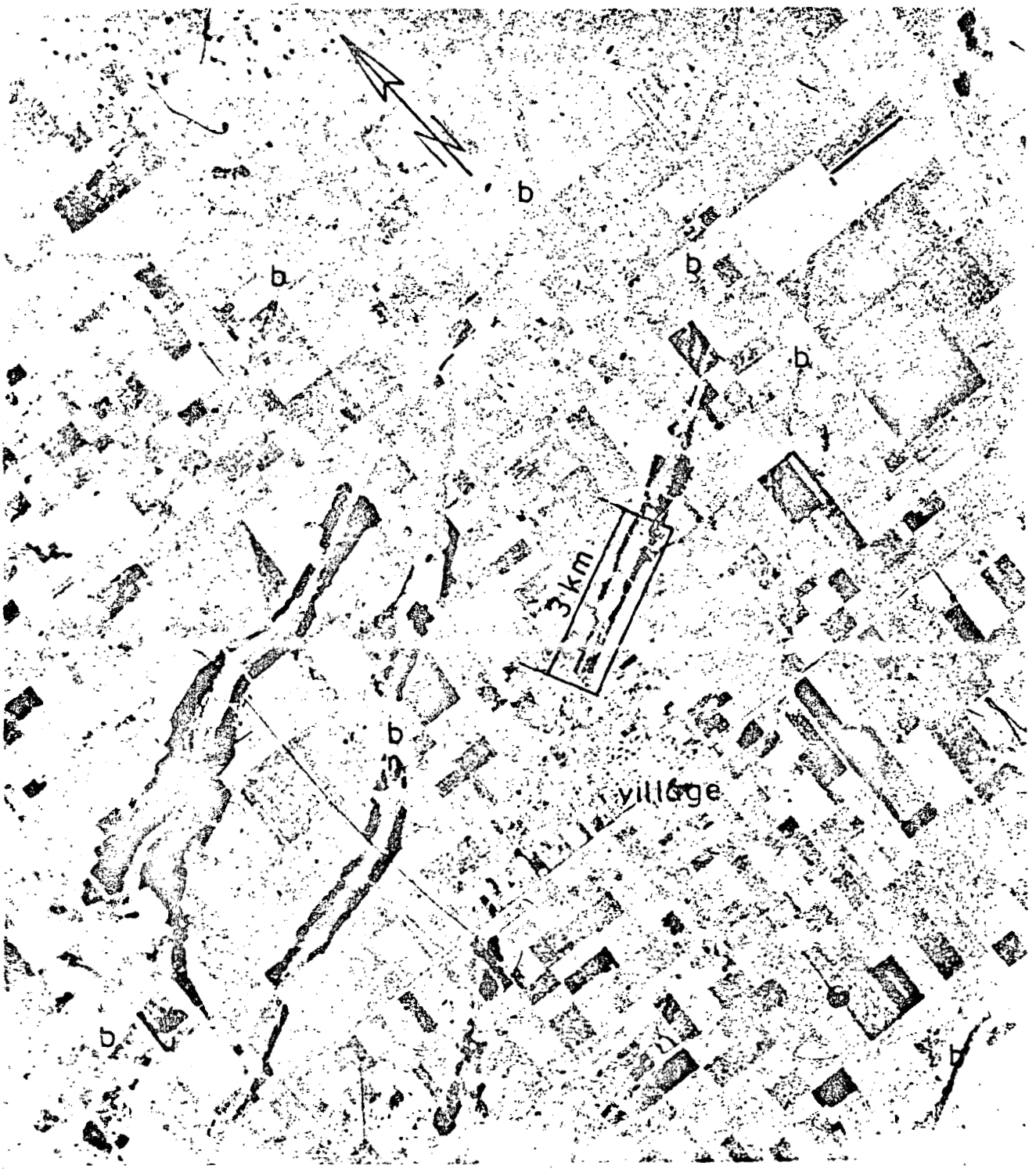
Ohm · m	salt content g/l
7	~ 1
4	~ 1,8
2	~ 3,5
1	~ 7

Isolines of apparent resistivity (Ohm · m)

Fresh ground water (7 Ohm · m)

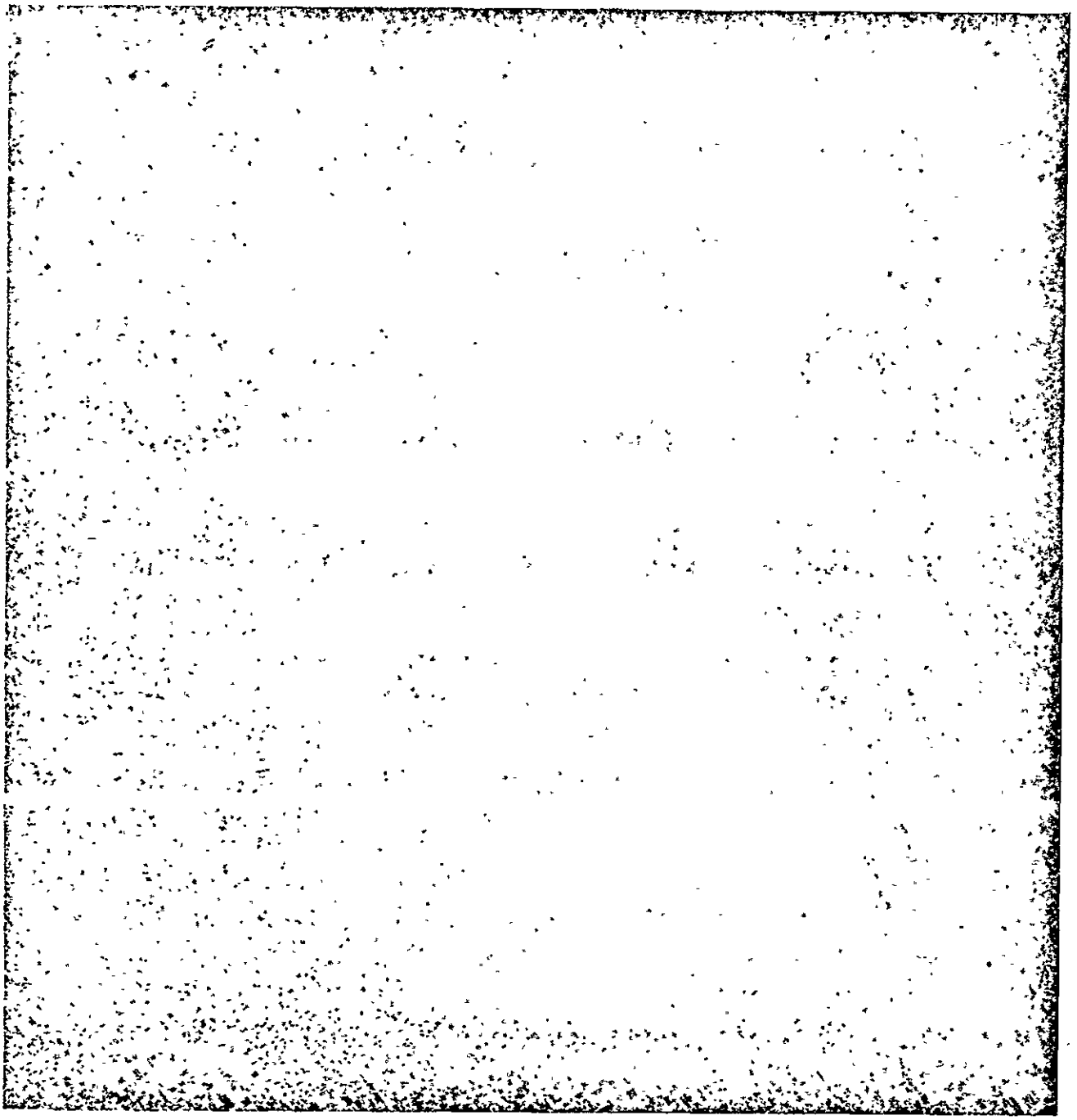
Fig. 3

Enlargement of an area with „bajos" (b)

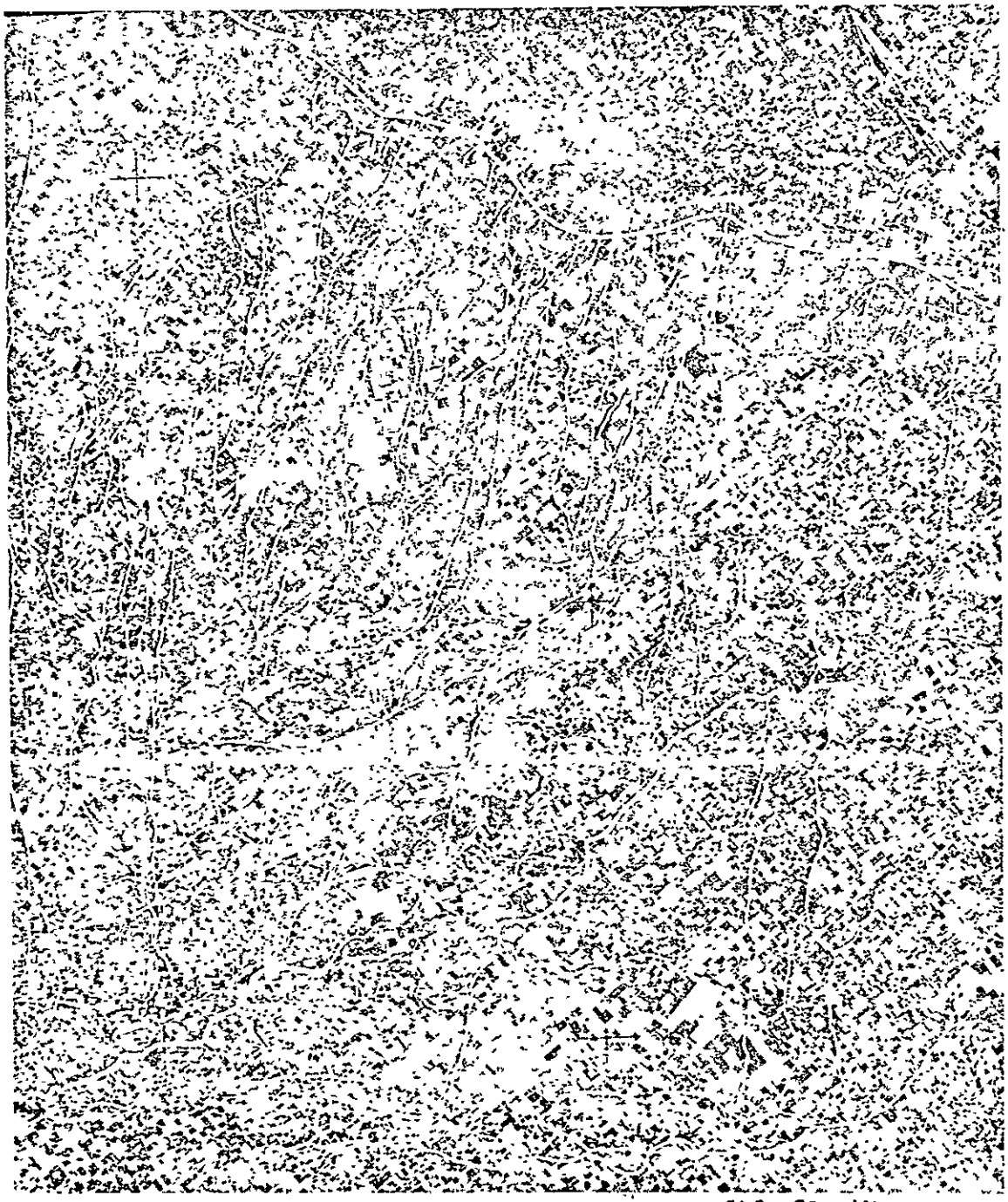


Boxed bajo section used to demonstrate estimation of fresh ground water reserves (see text)
Photograph Earth Terrain Camera

Fig 4



Ancient drainage pattern and current course of the Rio Tercero



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0 25 km

Fig. 5

STUDY OF SOIL AND VEGETATION

Pedological units were delineated on an IR color photo showing about 13,000 km^2 of Corrientes province, Northern Argentina (Fig. 6). No ground truth has been carried out in this region. The investigation was possible only by comparison of different colored and textured units on the photo with the pedological units on the SOIL MAP OF THE WORLD (FAO, UNESCO 1971), as well as by analogic conclusions from the project area further in the Southwest.

The soil types delineated on the SOIL MAP OF THE WORLD (1 : 5,000,000) can be correlated with units on the photo. Locally, due to its larger scale, the image allows a further differentation, e.g.: East and West of the Rio Paraná where exclusively mollic planosols are delineated on the map. In the Western area where a number of open waters and more intensive vegetation can be observed, the distribution of hydromorphic soils is taken into account.

The sediments in the investigated area are of fluviatile and aeolian origin. The soil moisture is influenced by the river floods and depth to ground water. A clue to estimating depth to water is the distribution and accumulation of open waters assuming that the sediments are permeable.

Different intensity and chlorophyll content of vegetation is imaged by different red tones on the photo. This is an important criterion for soil type identification as the predominant natural vegetation in this region reflects the genuine connection between vegetation, soil and climate.

Soil types in the investigated area

The pedological symbols and the description of soils, vegetation and lithological units were drawn from the SOIL MAP OF THE WORLD.

The predomination of sand or clay in a soil type, which could be detected on the image, has been marked as index s (= sand) or c (= clay) over the soil symbol.

- Wm_c - = Mollic planosols (predominantly clayish)

Image characteristic: (I.C.)

Predominantly pale pink tones, insignificantly textured areas. Regular soil conditions. No agriculture.

Deep eroded river beds, refer to deep ground water table. Green-blue and blue patches in the drainage area of the rivers, show areas with high soil moisture and some open waters, near surface ground water.

Soil units in the Province of Corrientes

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We_s	Eutric planosols, sandy
We_c	" " , clayey
Wm_s	Mollic planosols, sandy
Wm	" " , clayey
Je	Eutric fluvisols
Gm	Gleysols

- Gm - = Gleysoils

L.C.	Predominantly red-brown purpur with stripey texture, e.g.: on the riverside meadows of the Rio Paraná. Probably vegetation of hydrophile plants.
S.M.W.:	On the SOIL MAP this soil type is not delineated in the investigated area. Probably because of its small distribution it is connected to mollic planosols.

For the differentiation of soil types as seen on the Skylab photo the following criteria have been applied:

1. Color	Indicates the density of vegetation, the relative soil moisture and the soil sand content.
2. Texture	Indicates the distribution of natural vegetation and land use. The distribution of surface water and the nature of the drainage pattern gives an indication of the relief, the ground water conditions and the nature of the rock in the underground which influence the soil conditions.

The resolution of the Skylab photo also allows large scale pedological differentiation. It is an important tool for the preparation of pedological mapping and the determination of key areas in regions with natural conditions of vegetation. Its application allows a considerable reduction of field costs as ground conditions can be estimated and a preselection of the equipment is possible.

BENEFITS OF LANDSAT-1 AND SKYLAB DATA APPLICATION

About 20 available wells per 100 km^2 are needed for conventional reconnaissance mapping of depth to water and salinity in the Pampa.

Large scale mapping for water supply purposes was carried out using about 80 wells per 100 km^2.

With the aid of Landsat-1 and Skylab imagery the number of observation points for reconnaissance mapping can be reduced by up to 50 % and for large scale mapping up to 75 %. This equates to a reduction of field costs from 600 $ to 300 $ (rec. mapping) or respectively, from 2,400 $ to 600 $ per 100 km^2 (large scale mapping).

In general Landsat-1 imagery sufficed for these evaluations. Only in cases where higher resolution is needed, e.g.: calculation of bajos fresh water reserves, do Skylab photos allow a more precise determination.

CONCLUSIONS

Satellite imagery in combination with ground investigations allows the identification and delineation of the near surface ground water (depth to ground water, salinity). The degree of precision achieved is greater than that obtainable by conventional ground survey methods alone.

In future it will be possible to produce hydrogeological maps, cheaply and more quickly, of areas with similar climatological and hydrogeological conditions.

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